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Shane L. Larson
Utah State University

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EINSTEIN IN THE SKY: BLACK HOLE TALES FROM THE EDGE OF SPACE AND TIME

Shane L. Larson
Department of Physics
Utah State University

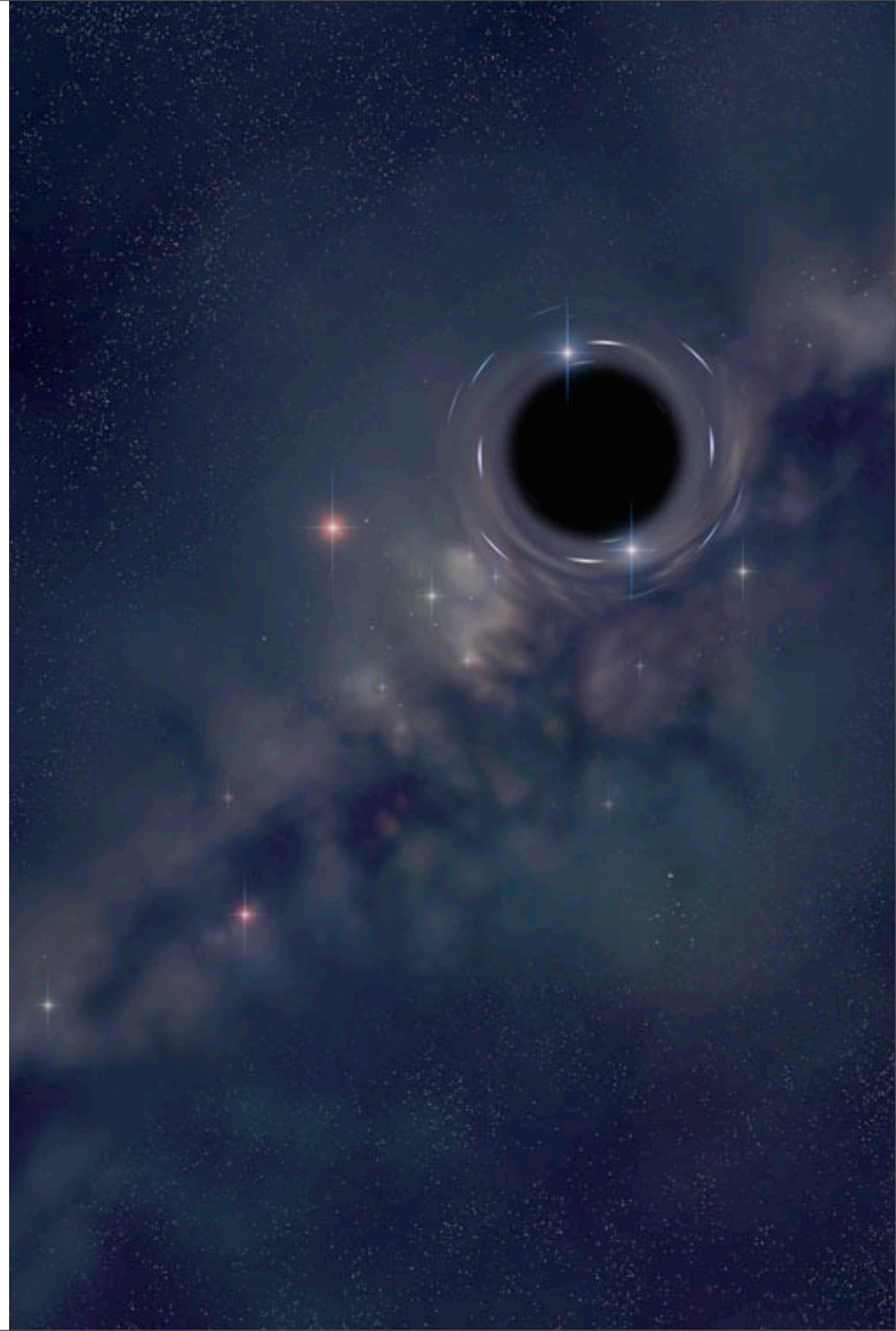
s.larson@usu.edu



AGGIE BLUE SKY NIGHT
USU – Logan, UT
8 October 2010

Storyline

- Black holes we have known
- Seeing black holes
- Listening to the songs of gravity



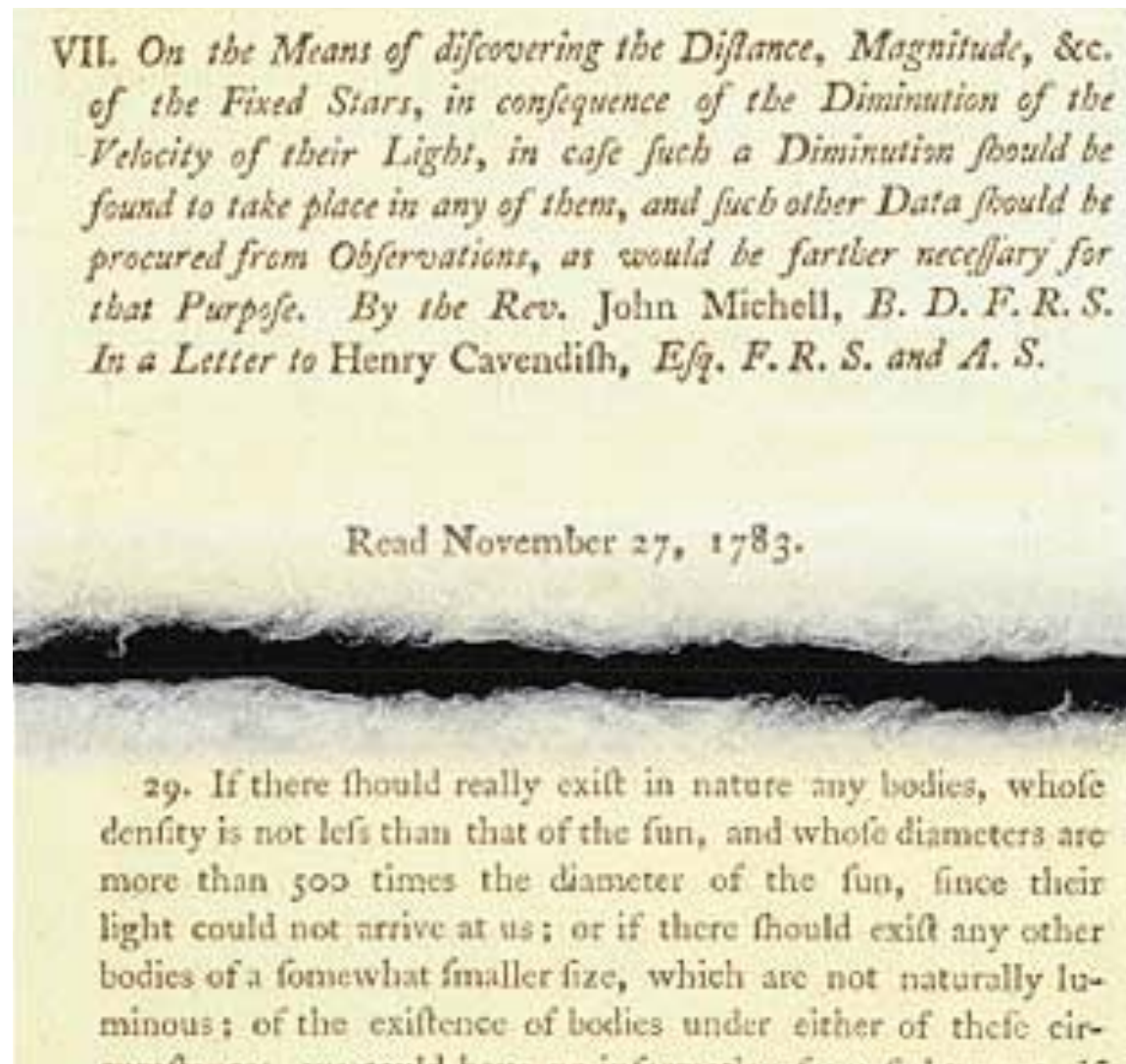
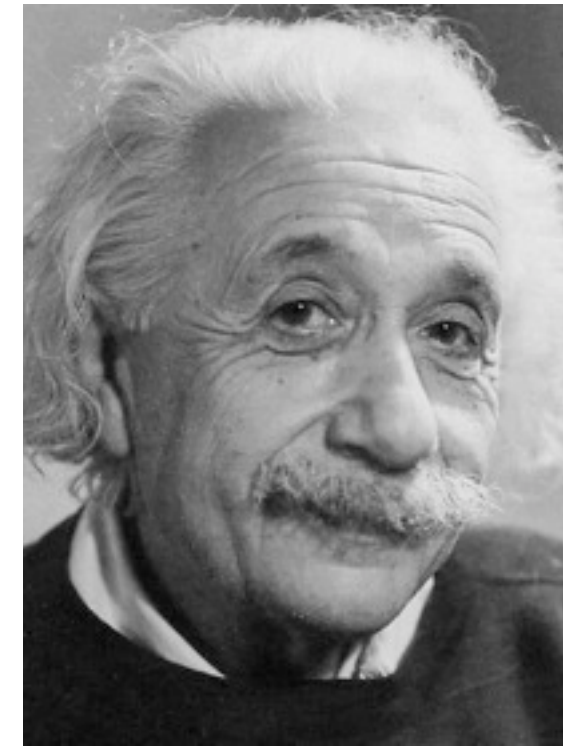
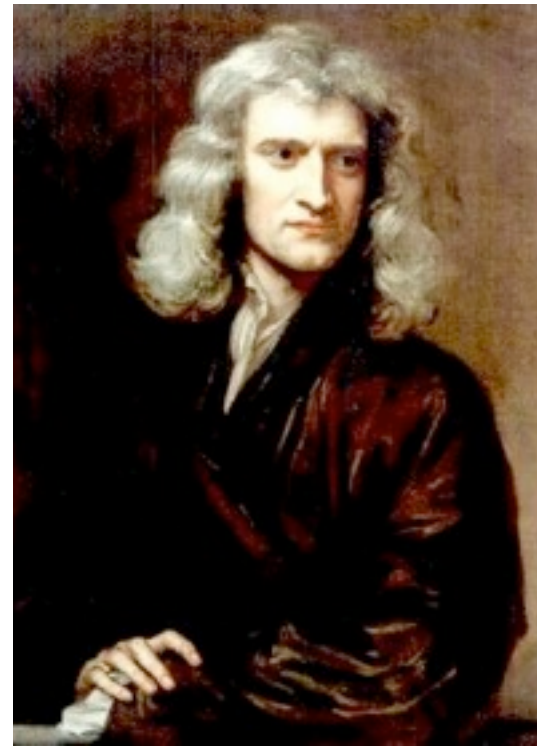
What do black holes look like?



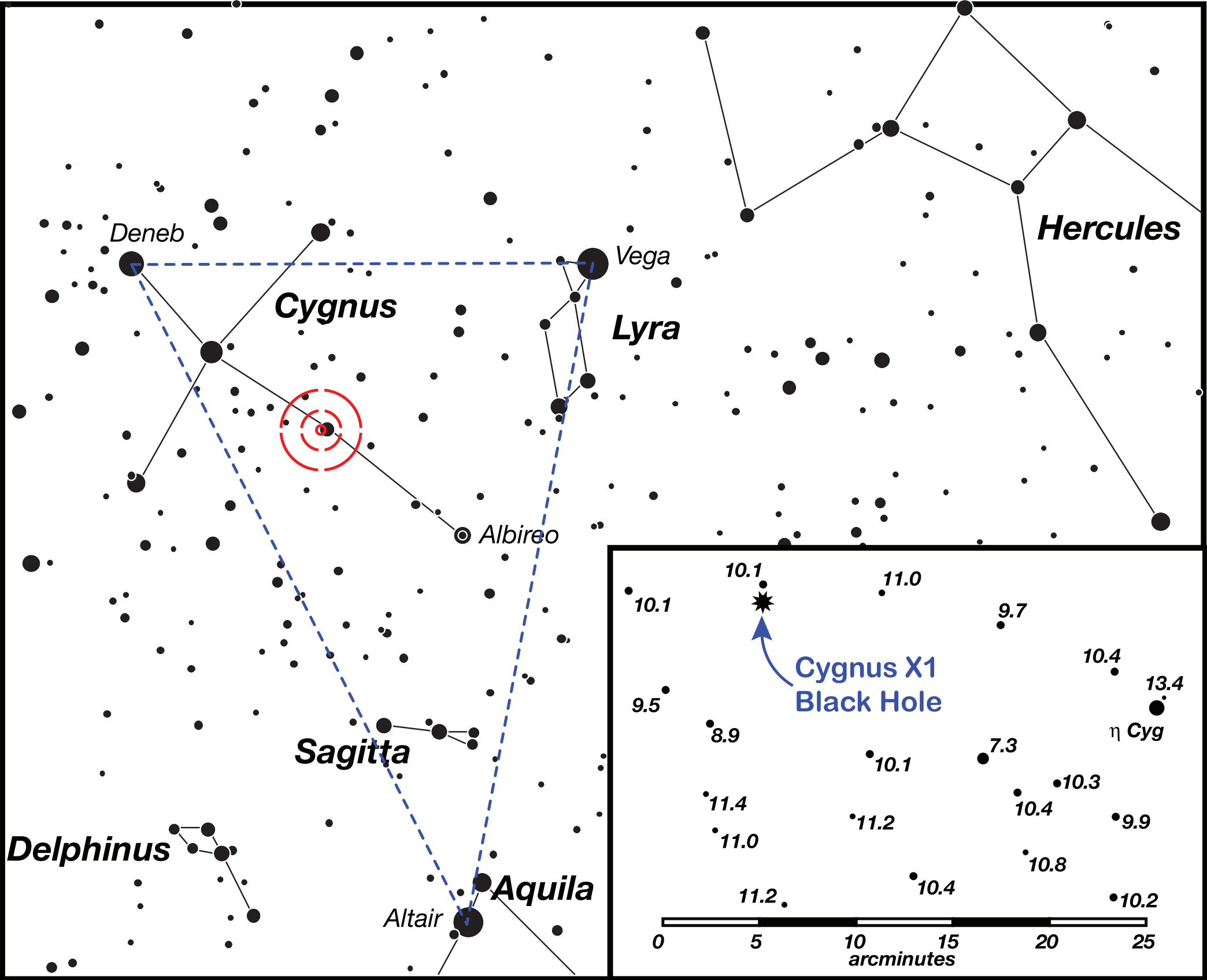
Image credit: M. Larson

Not a new idea!

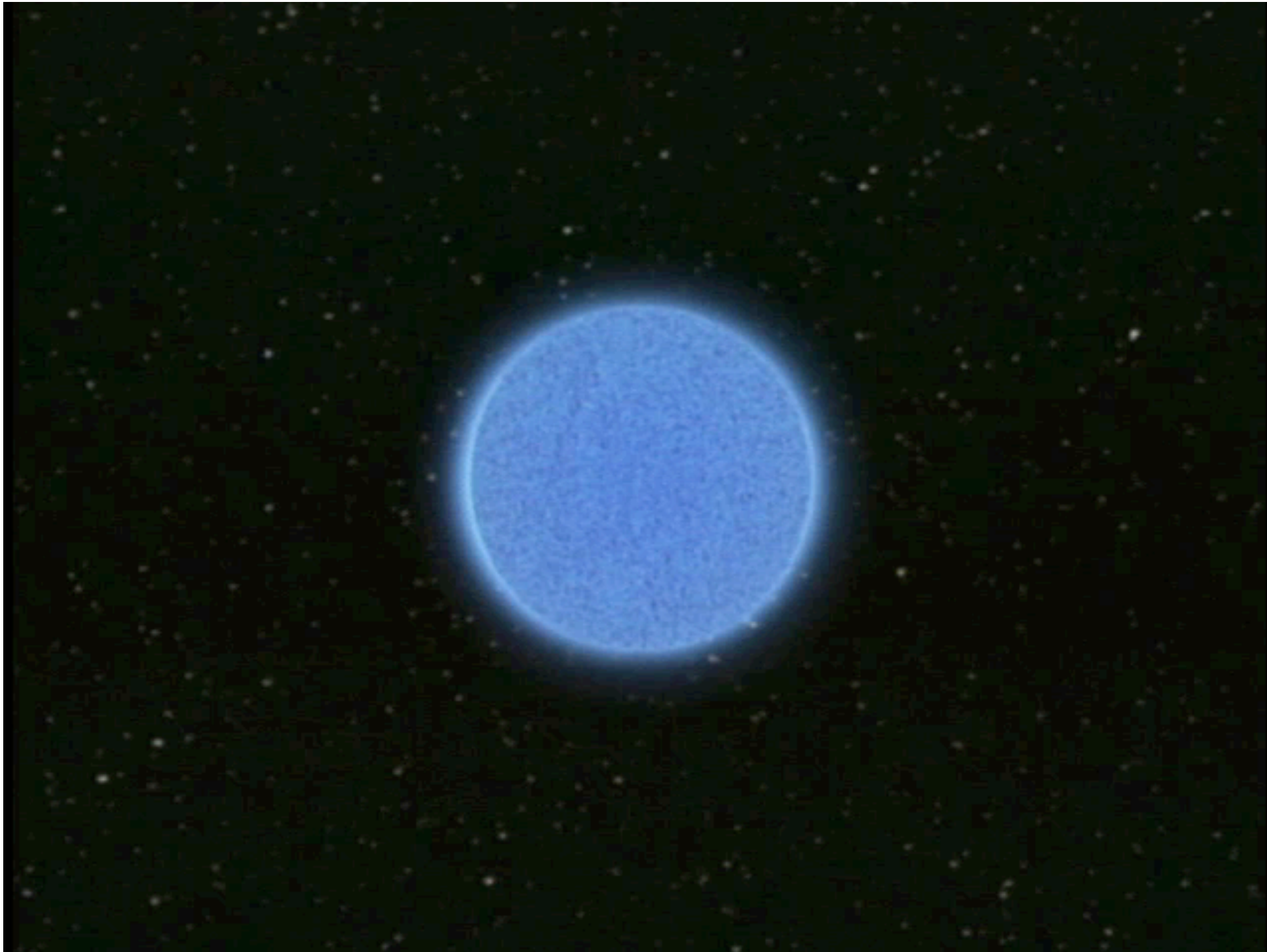
- **Einstein did not invent black holes!**
- Black holes are a **natural consequence** of gravity!
- Black holes were discovered in **Newtonian gravity** by Rev. John Michell in **1783** (!)
- What did Einstein add to the idea of black holes?
 - **You cannot escape from a black hole**
 - **The speed of light is a maximum speed limit (special relativity)**



Candidate: Cygnus X-1

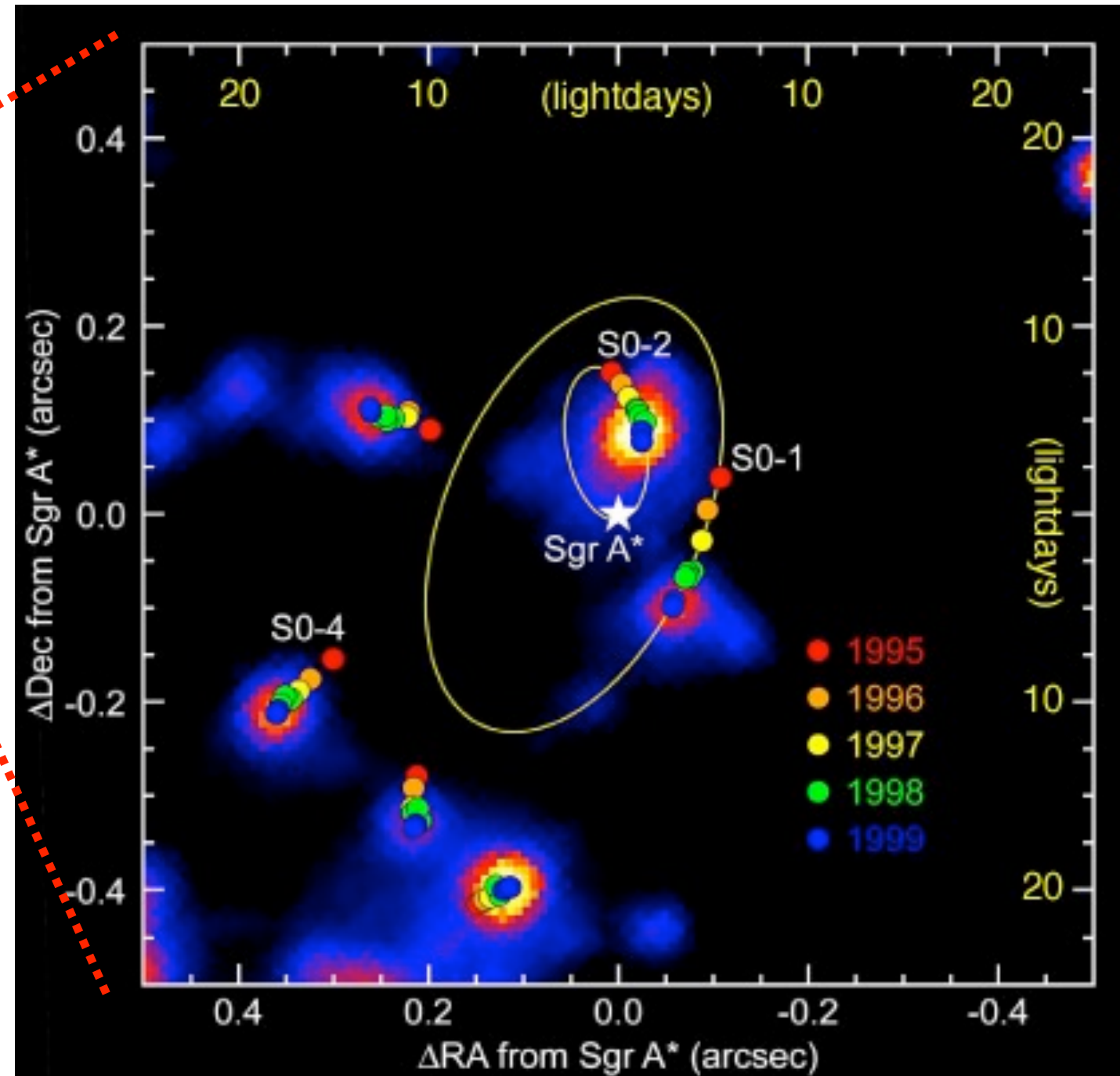
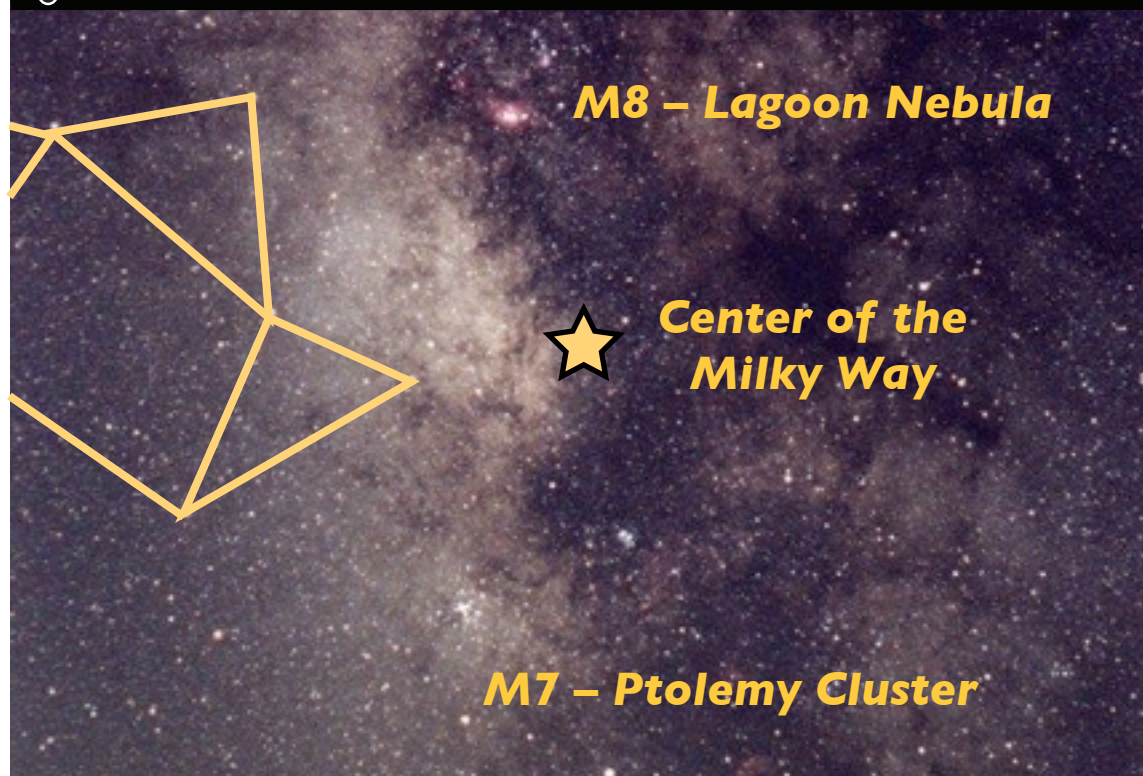
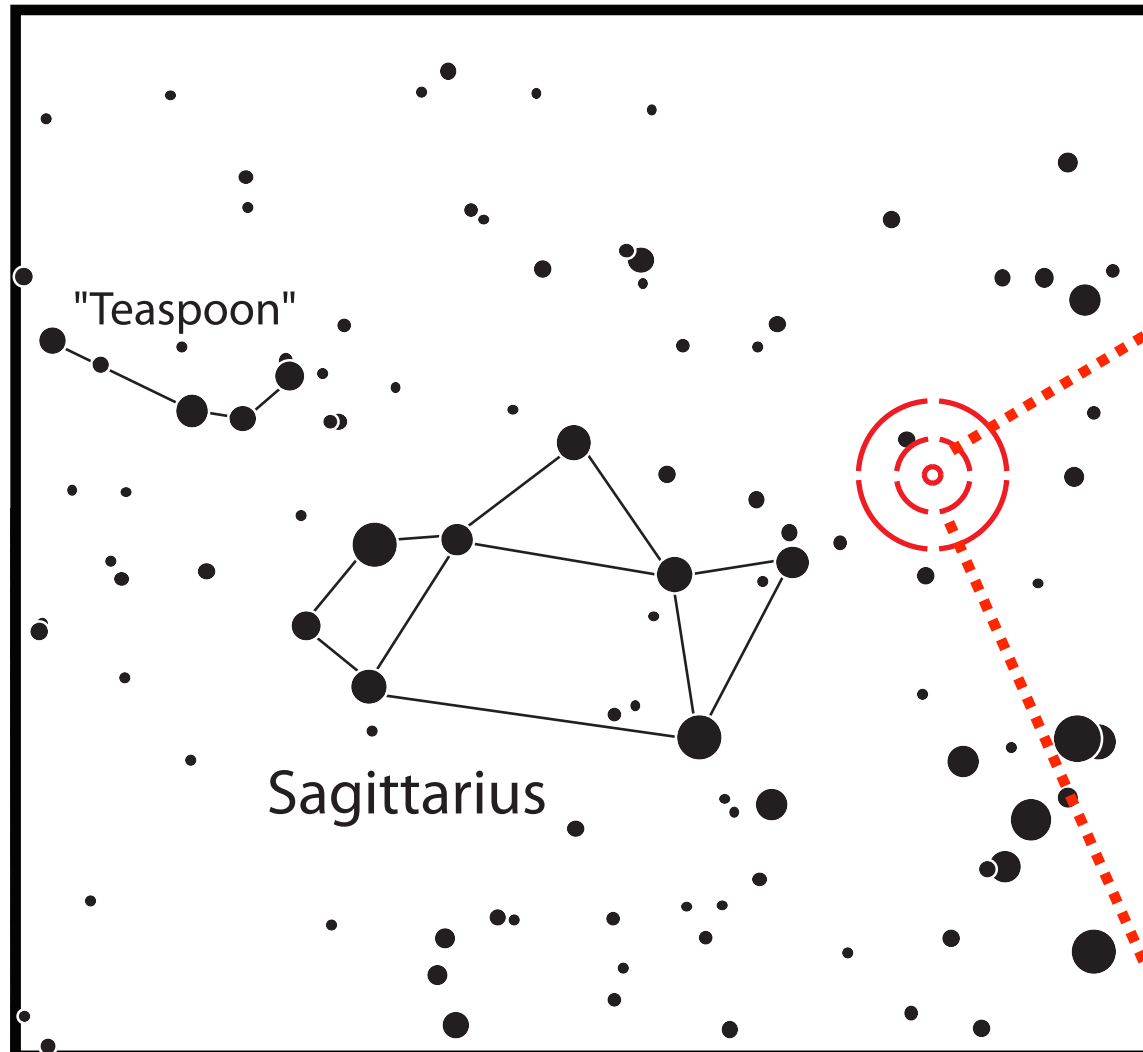


Candidate: Cygnus X-1

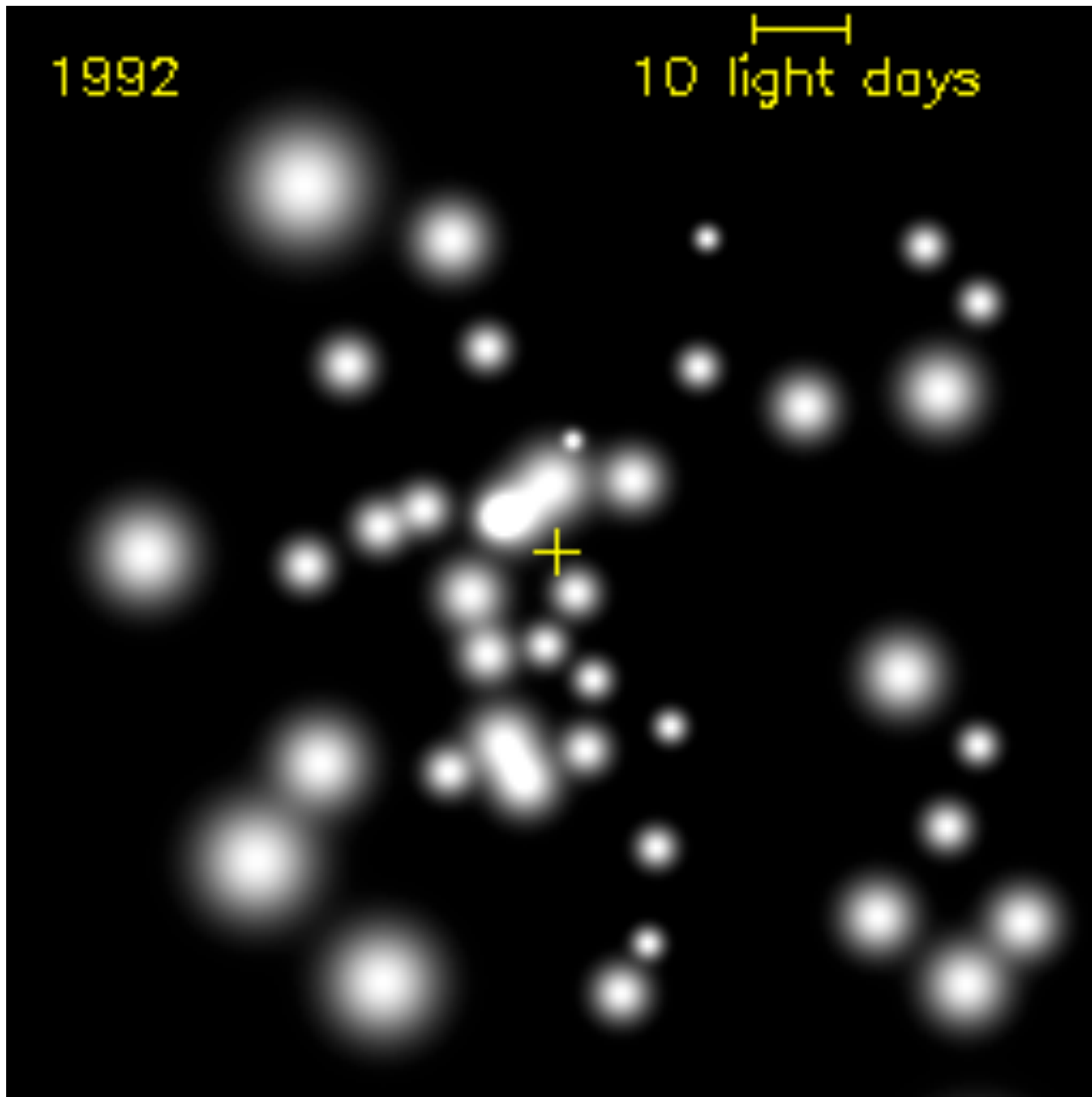


- Invisible companion of a blue supergiant star is a suspected 10 solar mass black hole – the closest black hole to Earth (~5900 lyr)!

Center of the Milky Way

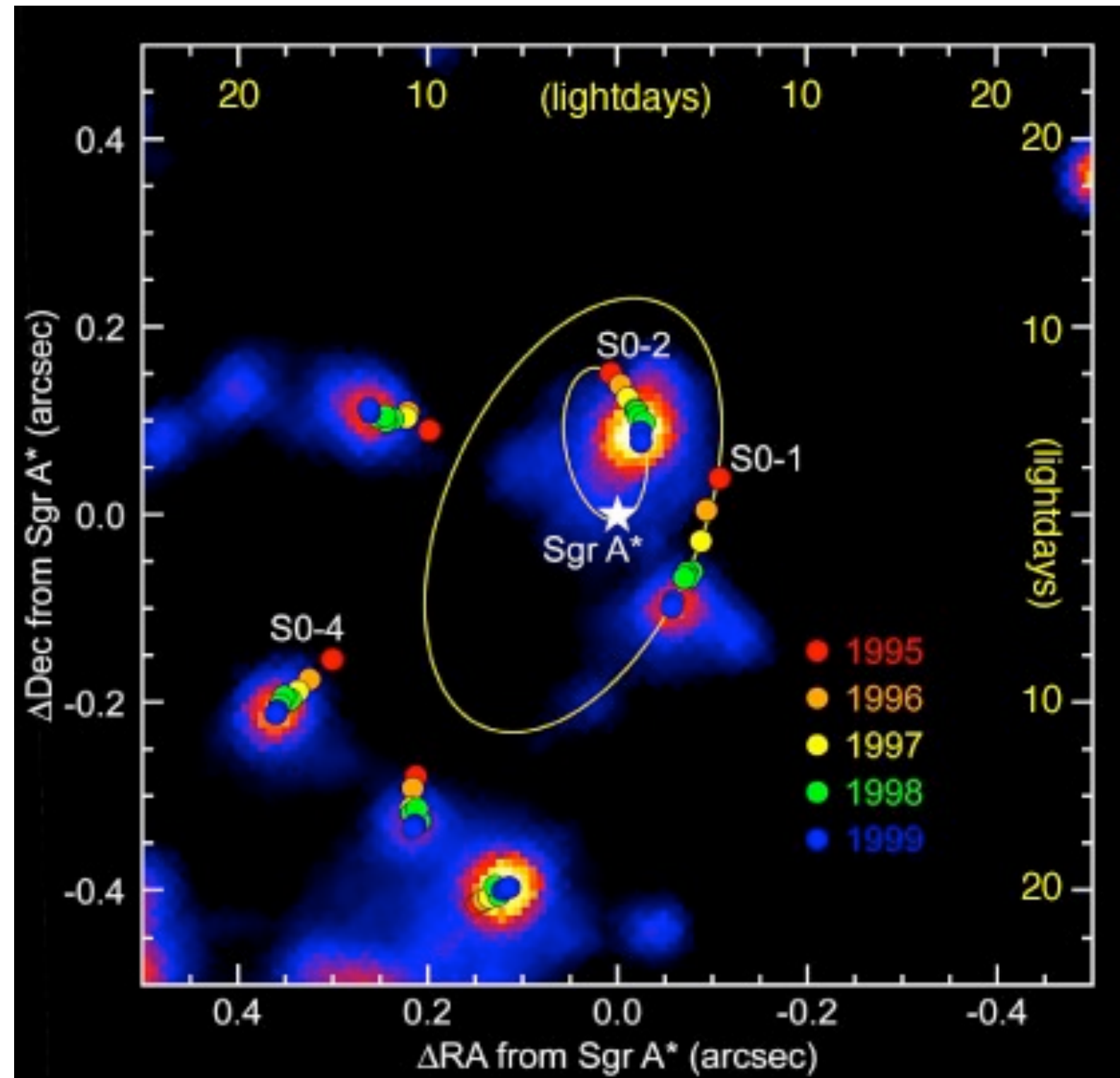


Stars in Motion...

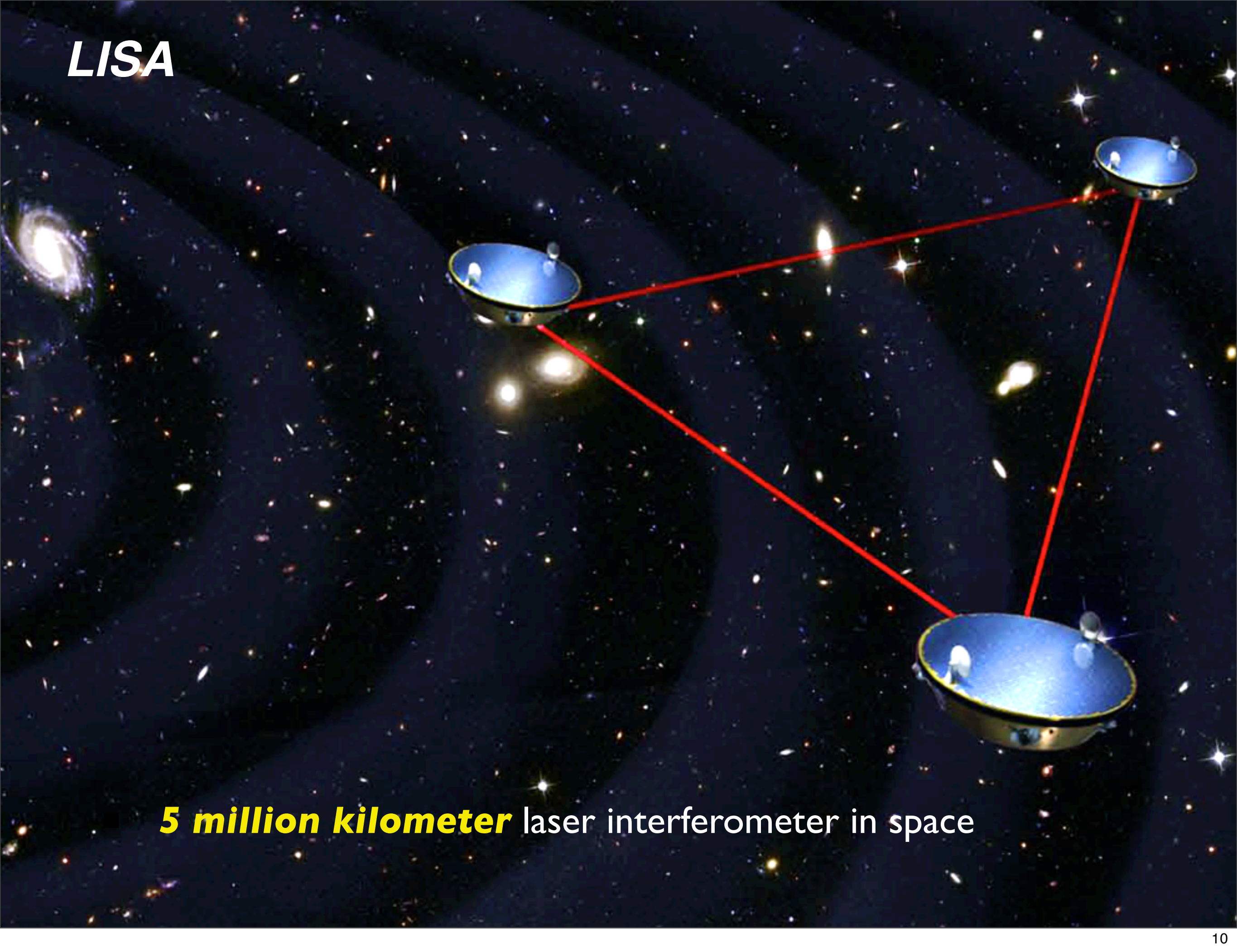


Explanation: 4 million solar mass black hole

- **Why do we think this is a black hole?**
- To explain the motion we see in the stars, you need 35 billion stars per cubic lightyear
- If this were caused by stars and not a black hole, there should be **90 million stars** in this picture!

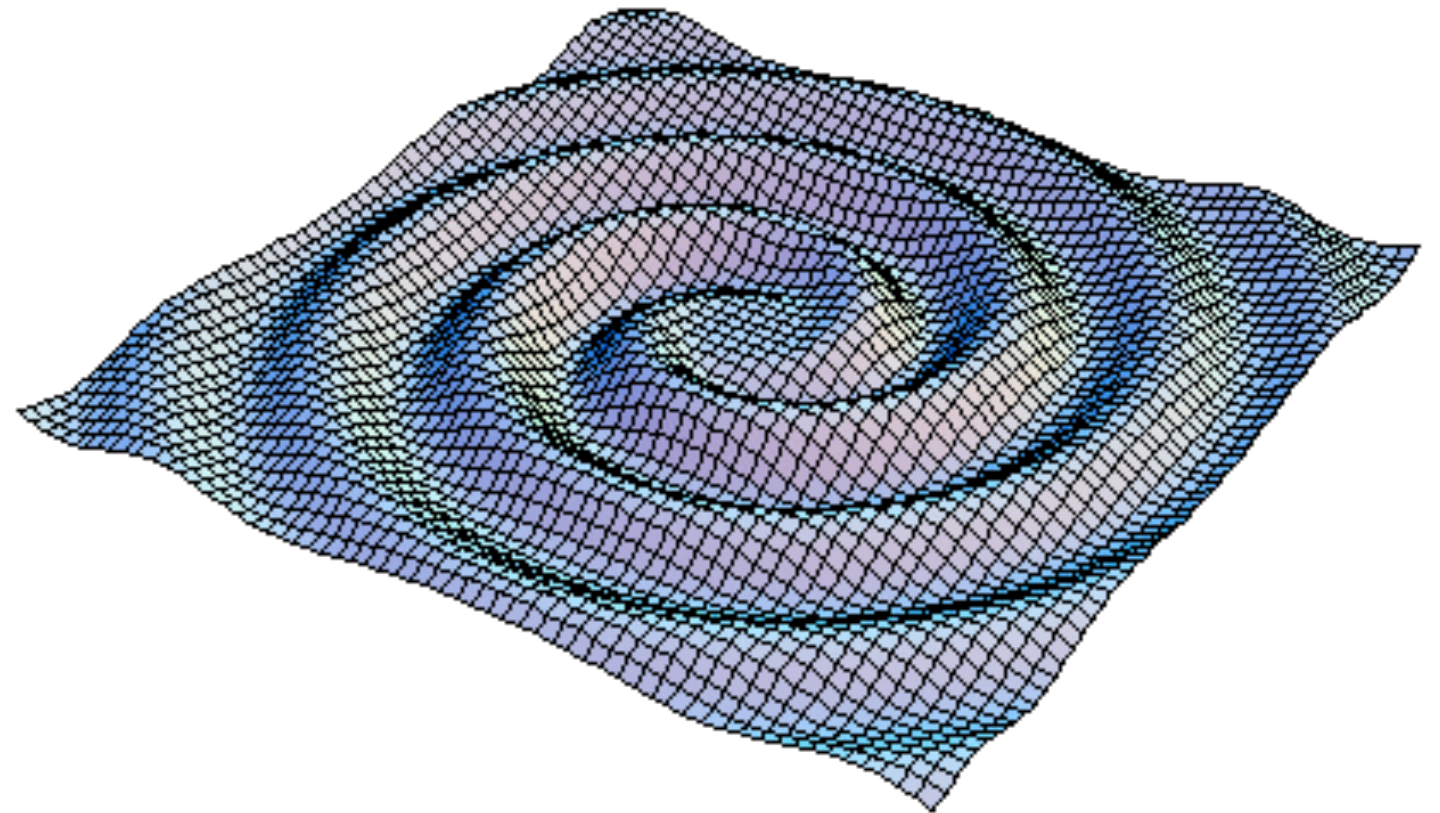
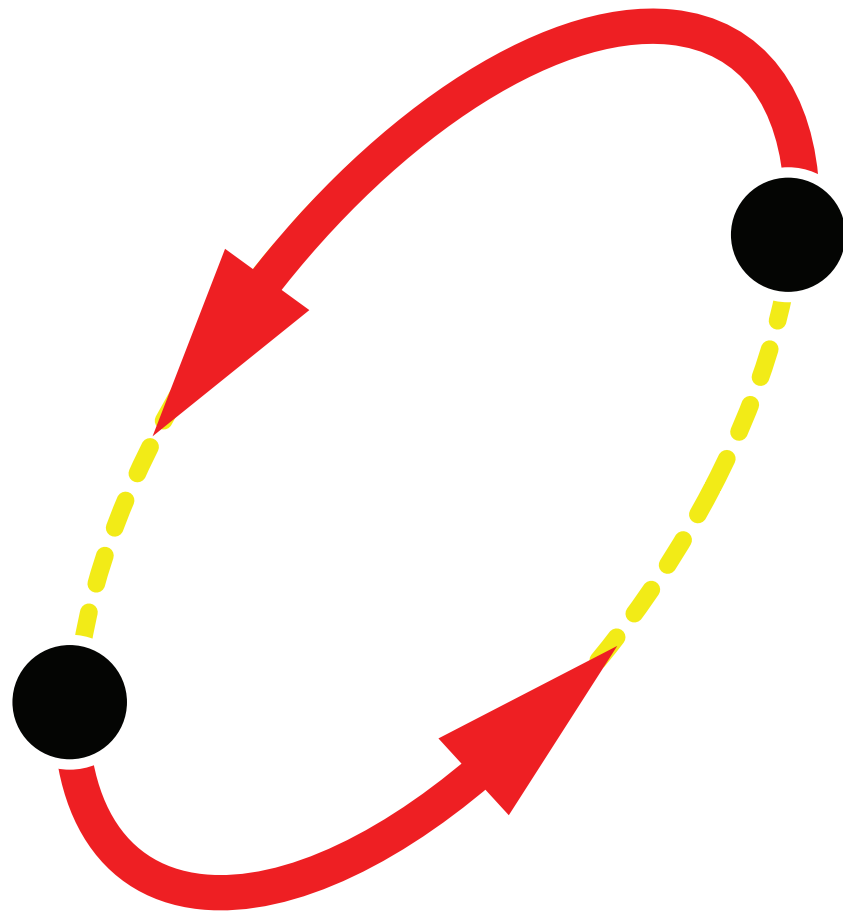


LISA



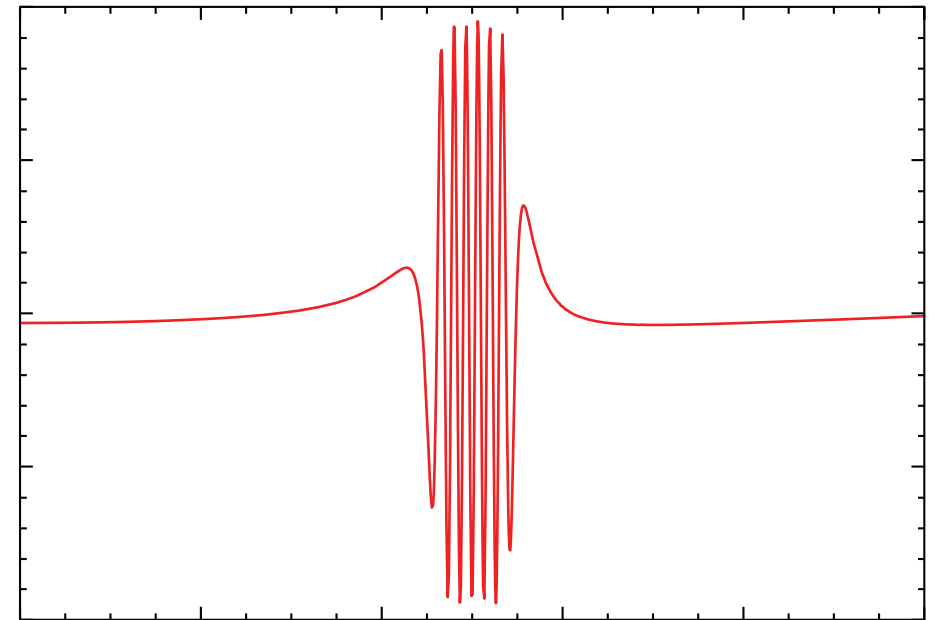
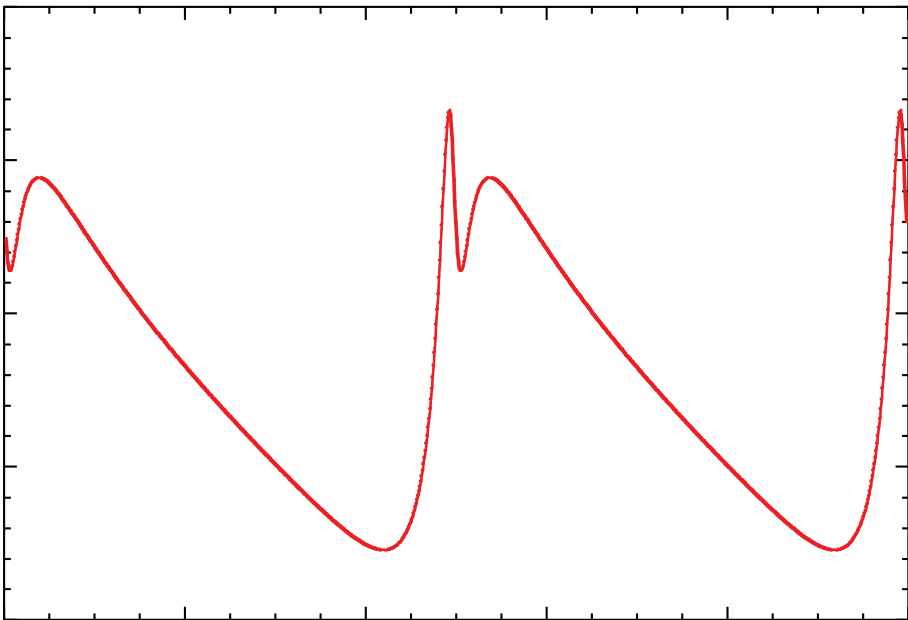
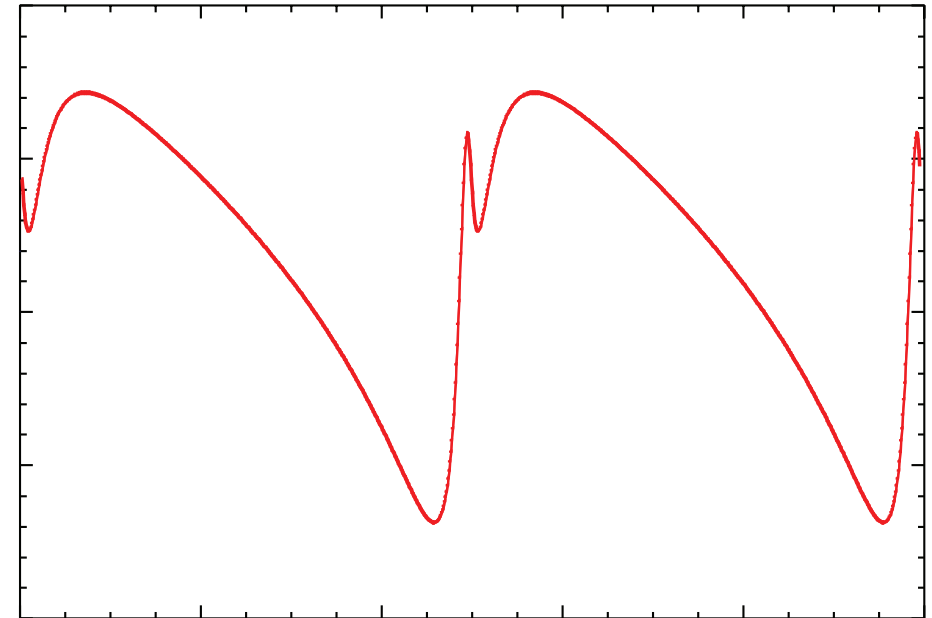
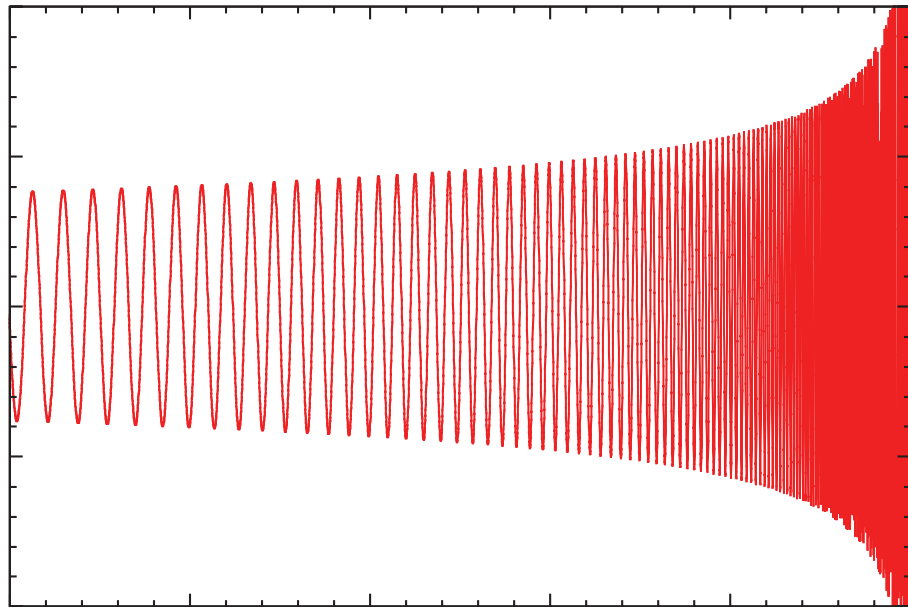
5 million kilometer laser interferometer in space

Binary Black Holes



- Half of all stars we see in the sky are binaries
- If stars evolve into black holes, then binary star systems can evolve into **binary black holes**!

Waveform Zoology



- Gravitational waves **encode astrophysical information!**
- They aren't good for making pretty pictures! :-)

The Songs of Gravity

10 M_{sun} BH + 10,000 M_{sun} BH
circular orbits

10 M_{sun} BH + 10,000 M_{sun} BH
eccentric orbits

More information, reading

- ALBERT EINSTEIN: www.aip.org/history/einstein/
- LISA: lisa.nasa.gov
- BLACK HOLES AND TIME WARPS (Kip S. Thorne)
- EINSTEIN'S UNFINISHED SYMPHONY (Marcia Bartusiak)
- EXPLORING BLACK HOLES (Ed Taylor/John Wheeler)

